Lake Champlain Basin as a Complex Adaptive System

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EPS 1101317

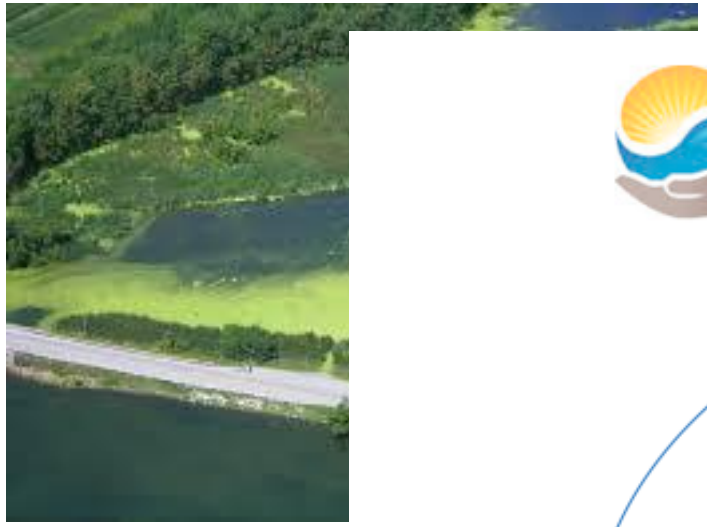
Our "Wicked Problem:"

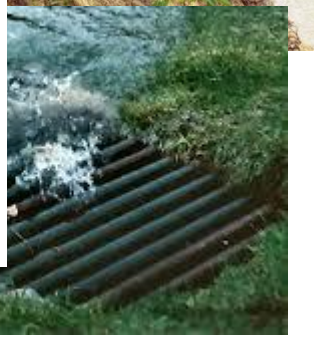
Algae blooms and phosphorus loading…

A *wicked problem* is a social or cultural *problem* that is difficult or impossible to solve for as many as four reasons: **incomplete knowledge**, the number of **people and opinions involved**, and the **interconnected nature** of these *problems* with other *problems.*

Our “Wicked Problem:”

Algae blooms and phosphorus loading…

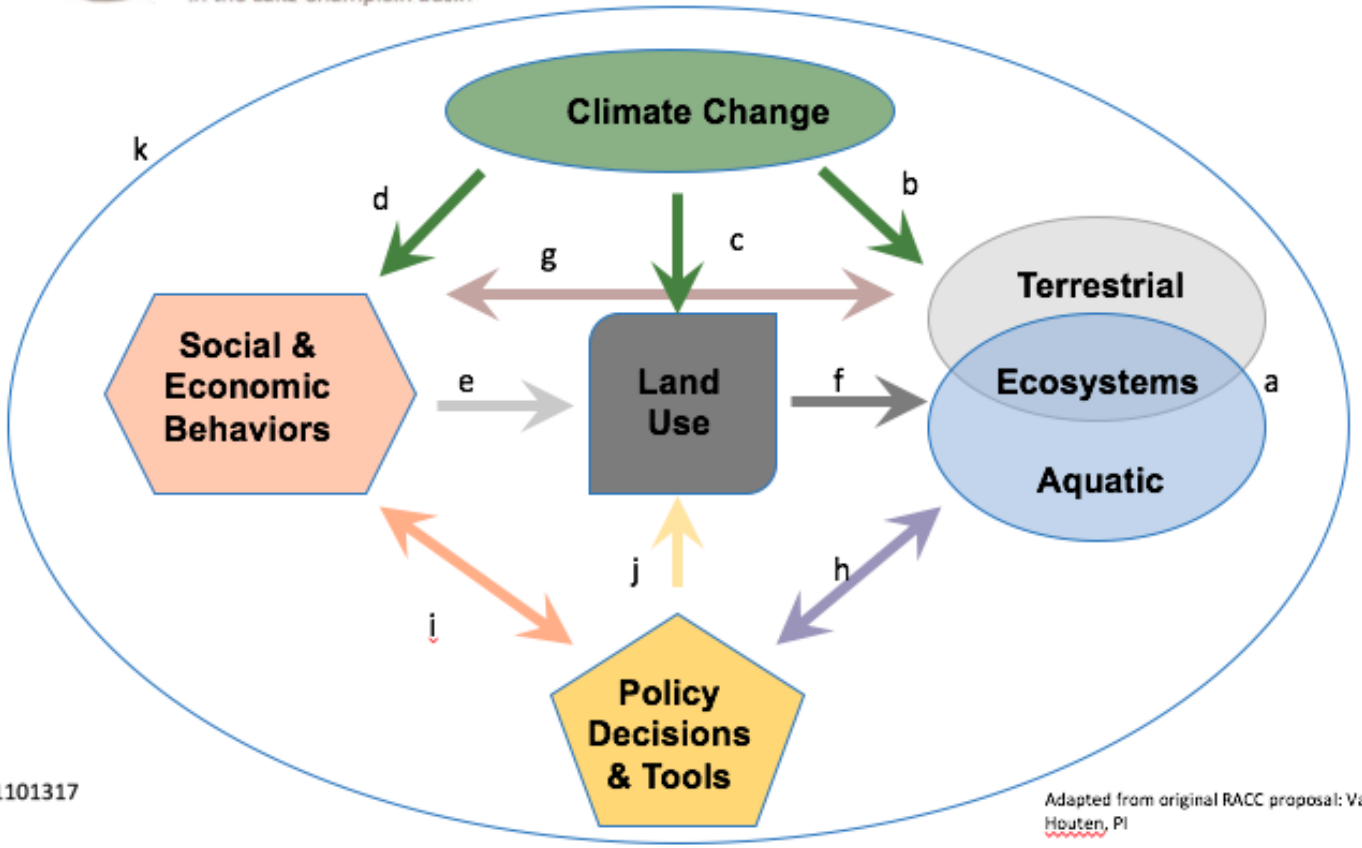




RACC

Research on Adaptation to Climate Change in the Lake Champlain Basin

RACC Model: LCB as Complex Adaptive System



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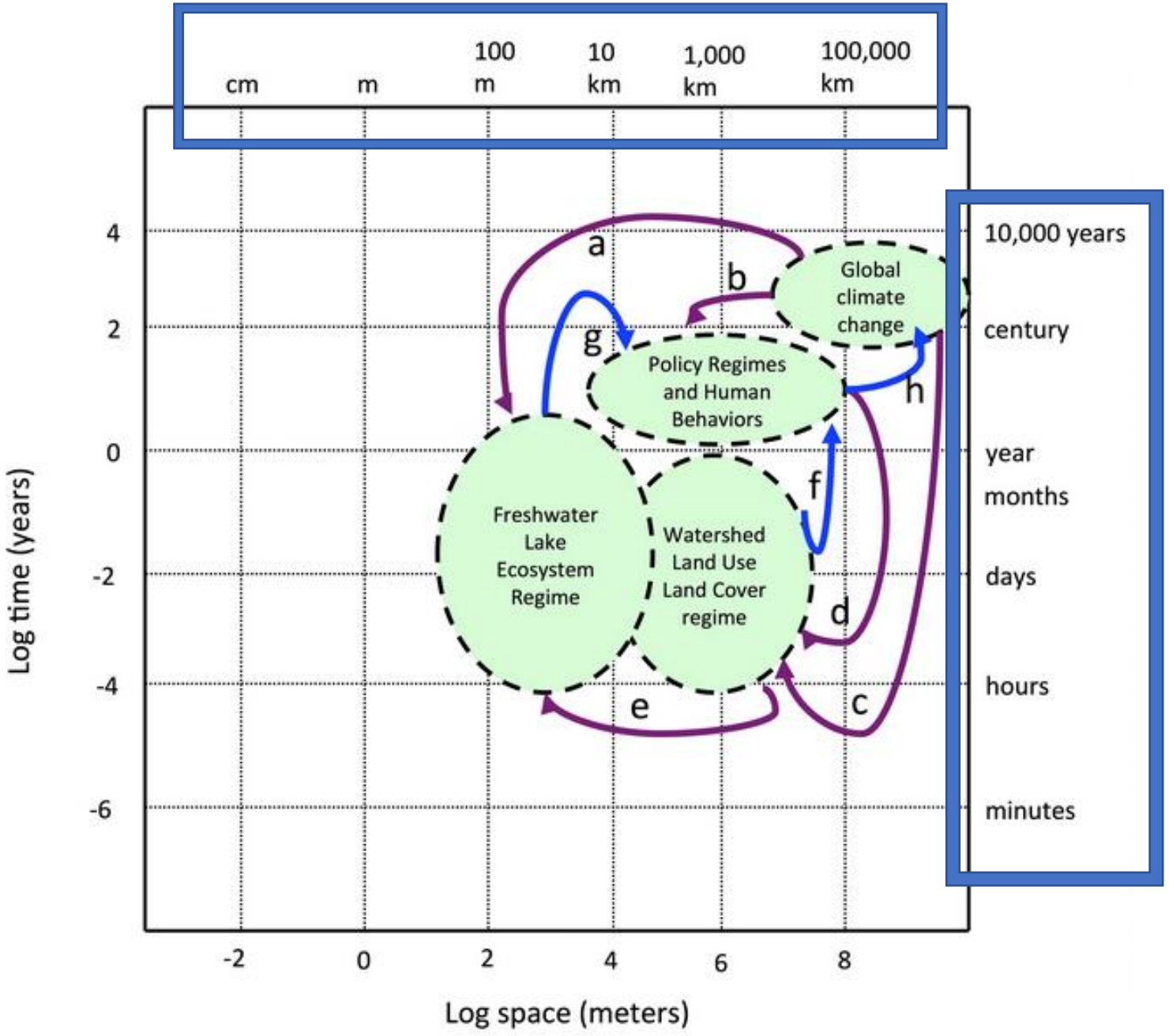
Adapted from original RACC proposal: Van Houten, PI

Complexity Across **Time** and **Spatial** Scales



THIS APPLIES TO ALL FRESHWATER WATER BODIES

Source: Zia et al., In preparation. Understanding Lags, Inertia and Cross Scale Dynamics in Social Ecological Systems

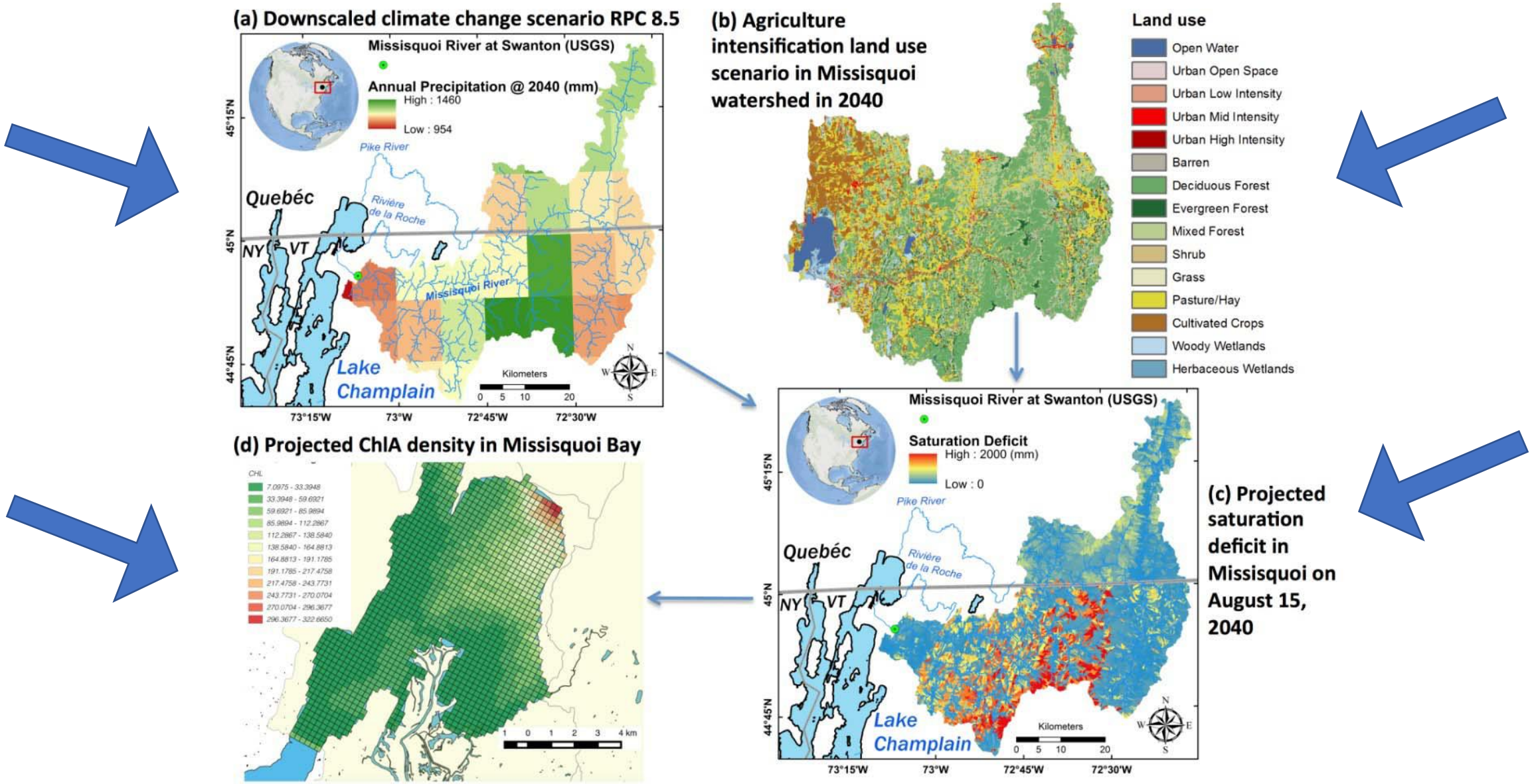
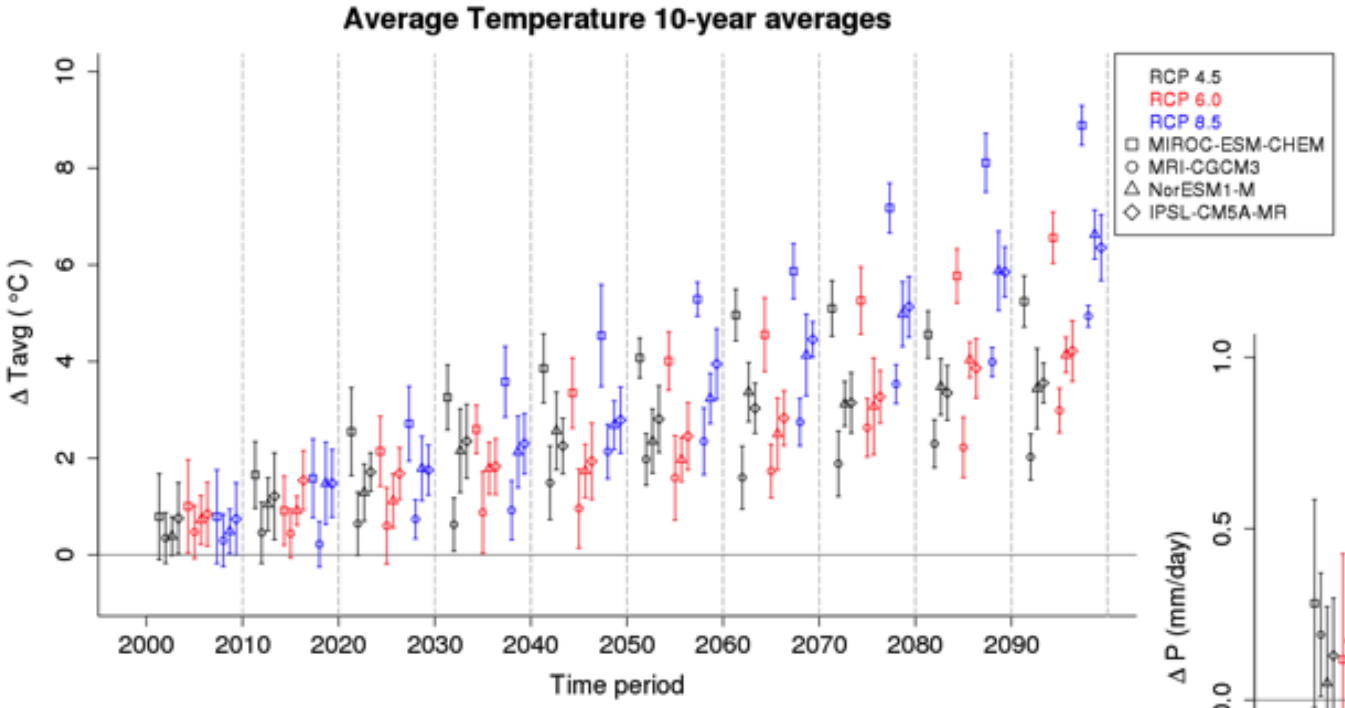
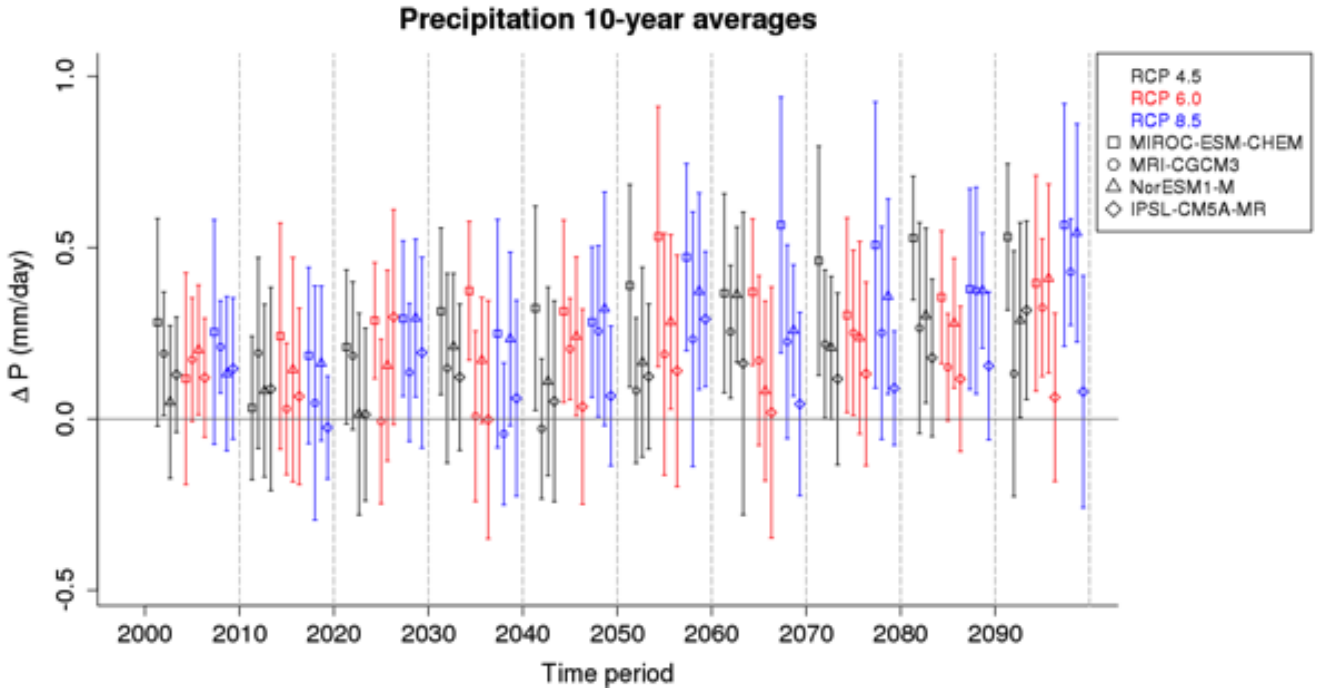


Figure 8. Output from cascading current Track-1 IAM that will be replaced by the BREE IAM: Output reveals (a) Projected precipitation by GCM BNU_ESM.1.rcp85 in 2040; (b) Projected Land-Use by Agent Based Model in 2040; (c) Projected hydrological scenario by RHESSys on August 15, 2040; (d) Projected Chlorophyll A (proxy for algae) concentration by A2EM on August 15, 2040.

Temperature and Precipitation Projections to 2090





Zia, A.,et al.., 2016. **Coupled Impacts of Climate and Land Use Change Across a River-Lake Continuum: Insights from an Integrated Assessment Model of Lake Champlain's Missisiquoi Basin, 2000-2040.** *Environmental Research Letters.* 11(11).

Zia et al., 2016

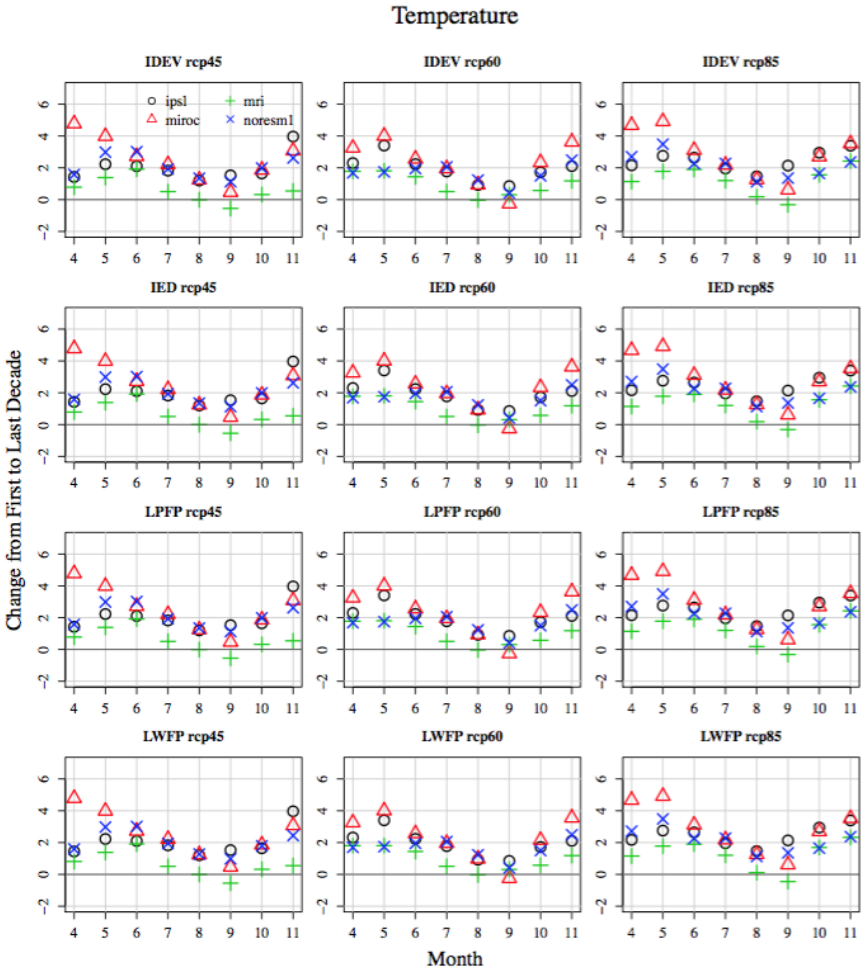


Figure 7: Projected changes in mean monthly lake temperature (˚C) from the first (2001-2010) to the last (2031-2040) decade of the simulation period. ΔTemperature is shown by month for each LULCC scenario (rows), RCP (columns), and GCM (symbols).

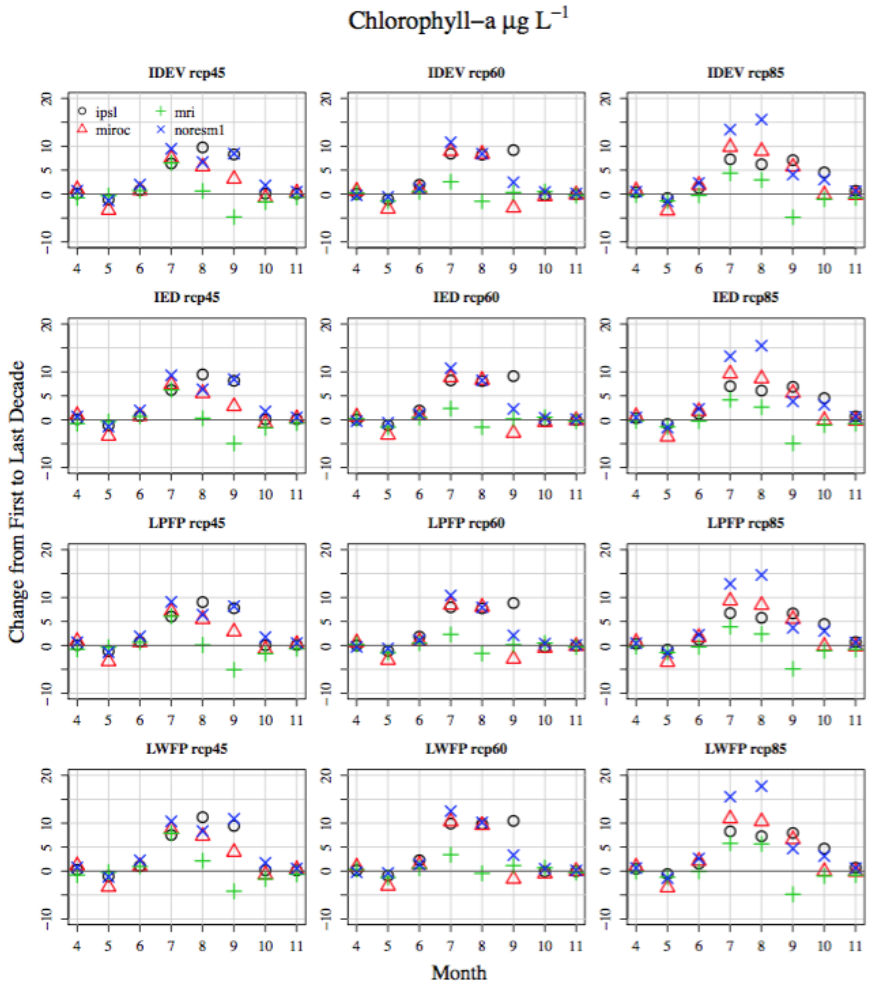
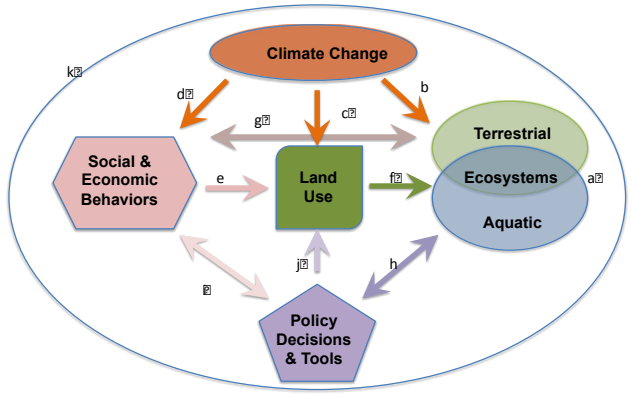


Figure 8: Projected changes in ChlA density (µg L^{-1}) during the growing season between first (2001-2010) and last (2031-2040) decades of simulation at long term monitoring station 51. ΔChlA is shown by month for each LULCC scenario (rows), RCP (columns), and GCM (symbols).

MISSISIQUOI BAY WILL LIKELY BE GETTING WARMER

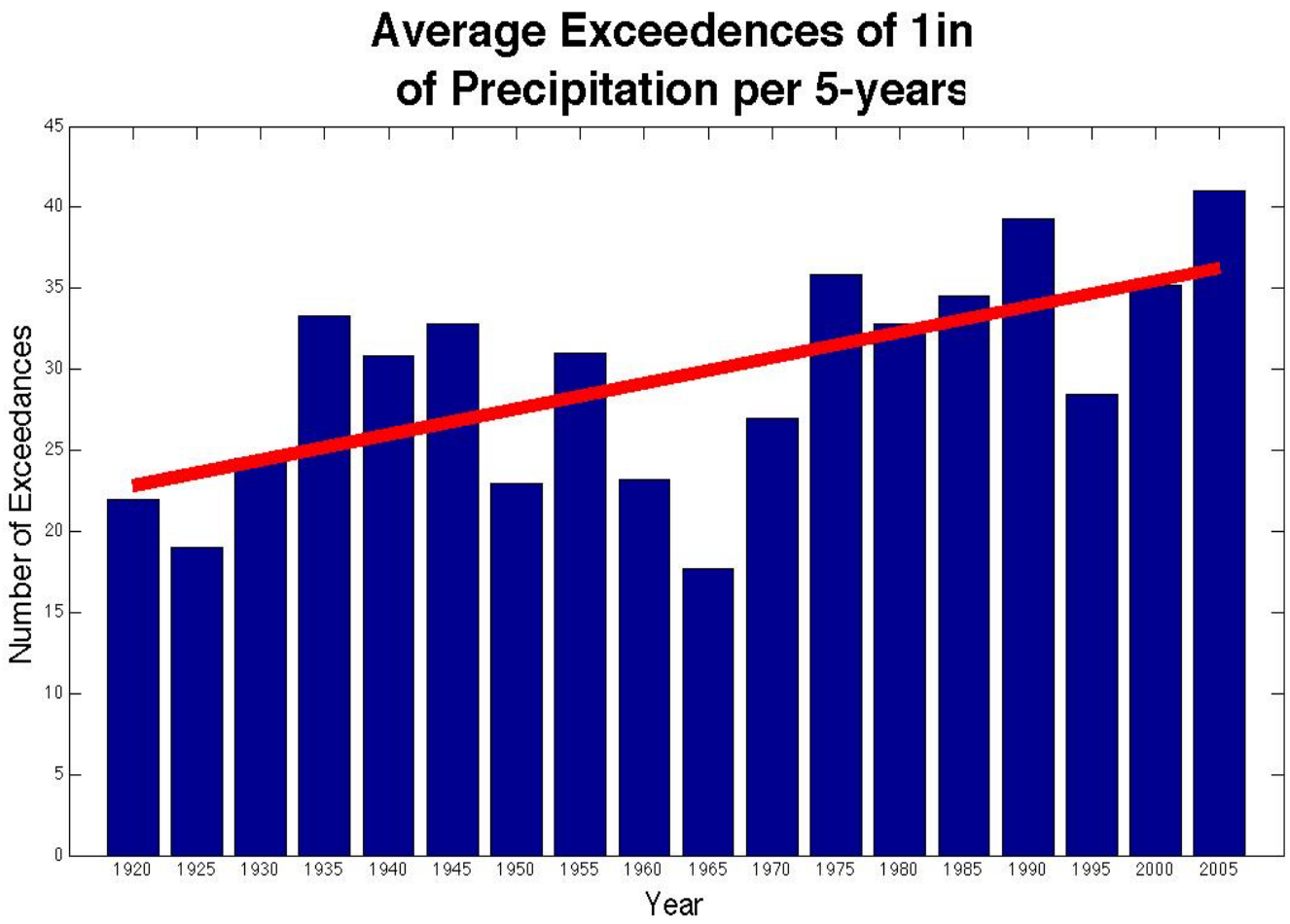
MISSISIQUOI BAY WILL LIKELY HAVE LONGER/MORE PERSISTENT ALGAE BLOOMS

Some policy-relevant findings from RACC:



- **Land use** clearly impacts stream metabolism
- **Storm events** impact total phosphorus (TP) levels.
- Water column stability impacts BGA blooms (**effects of winds and storm mixing**).
- **Legacy phosphorus** is a driver of shallow bay BGA blooms.
- Fish health is likely impacted by BGA blooms.

Climate drivers: precipitation is becoming more extreme in Vermont

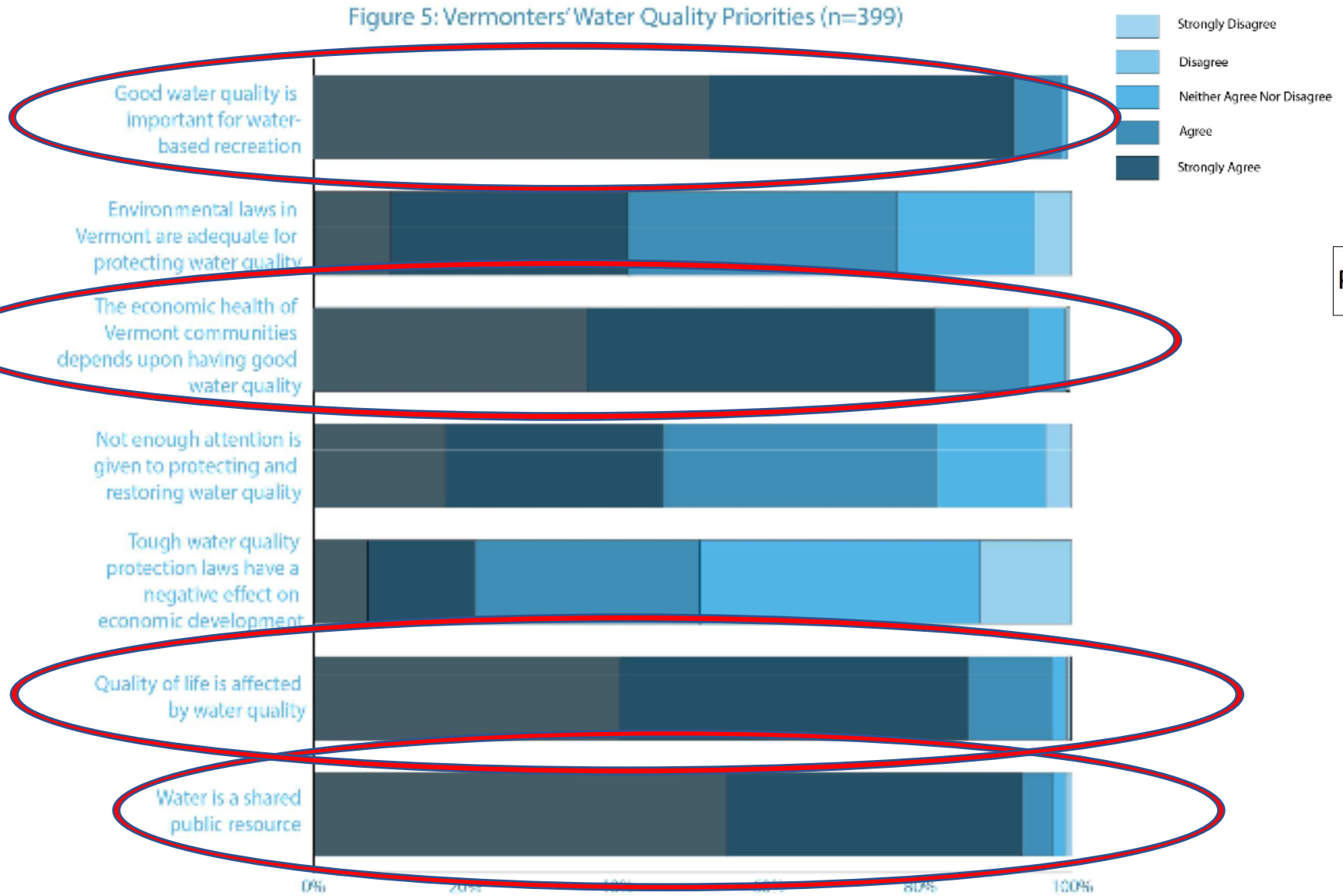


Co-Benefits of Flood Hazard & Clean Water Mitigation

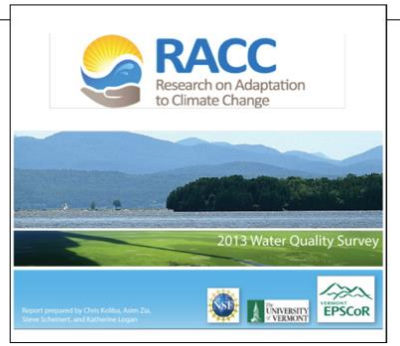
Bomblies, et al., 2016

BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

Water quality appears to be important to the public



Public opinion research



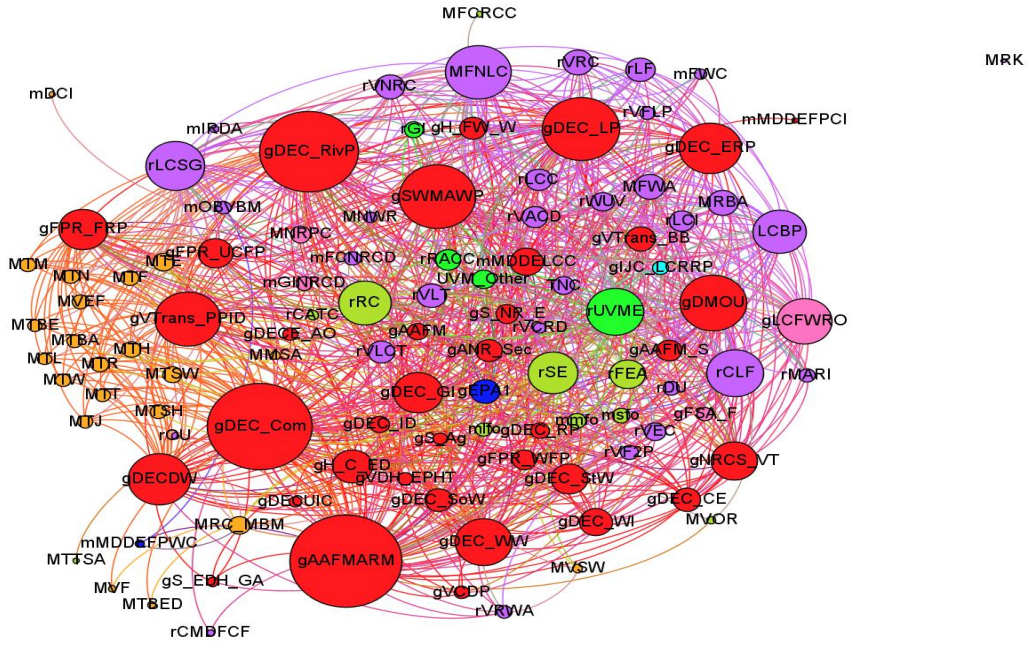
Castleton
Polling Institute

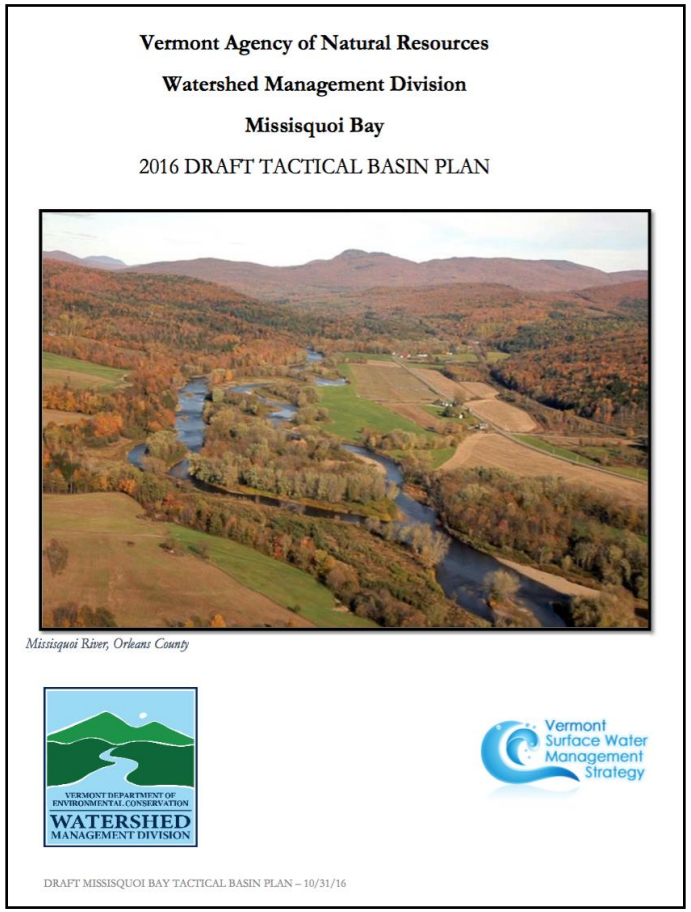
BREE
Basin Resilience to Extreme Events

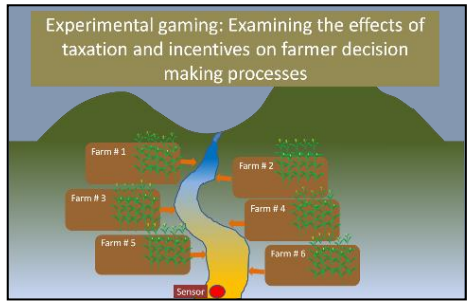
Source: Koliba et al. 2013 Vermont Water Quality Survey. University of Vermont

We Have the Right Mechanism in Place to Allocate Resources: **Tactical Basin Planning**

NEED → PROJECT → LAND OWNER CONSENT → FUNDING







Land User Consent: Human Behavior is Complex

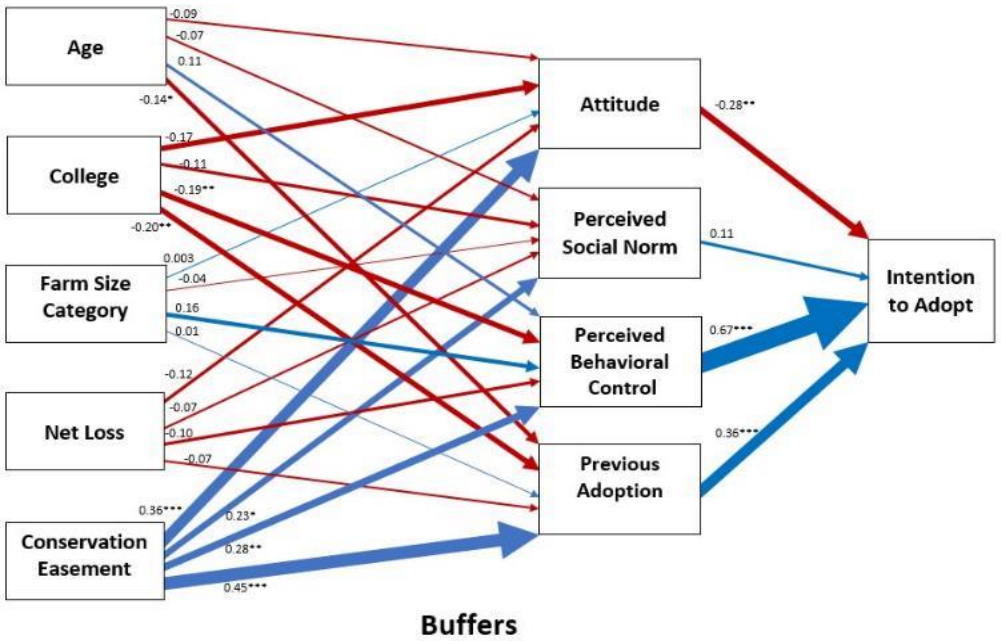
NEWRnet
North East Water Resources Network

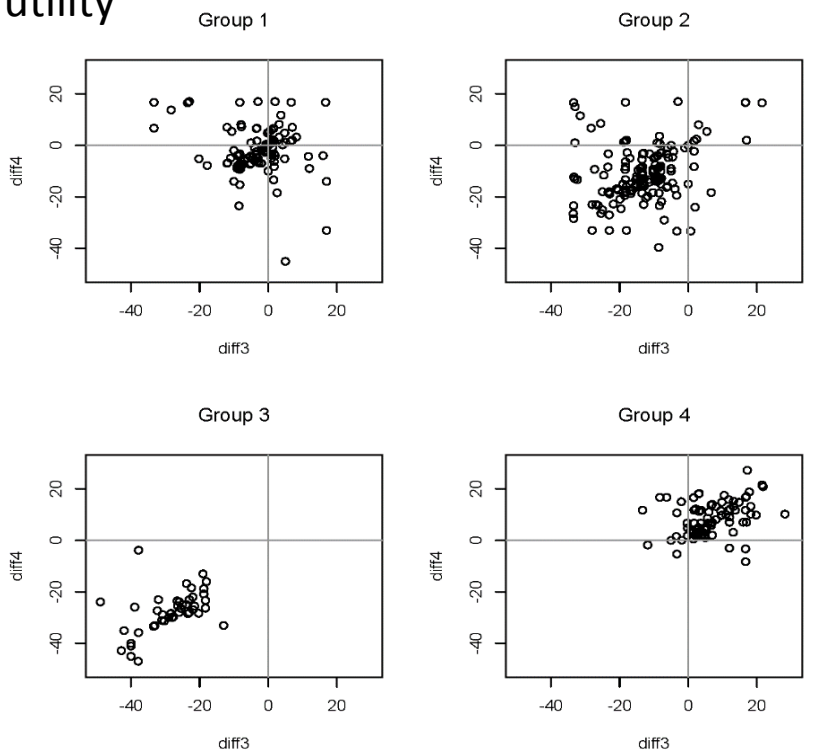
SEGS Lab
social ecological gaming and simulation
Harnessing complexity to solve problems.

Competitive/utility maximizing

Cooperative

(Tsai et al., 2015)





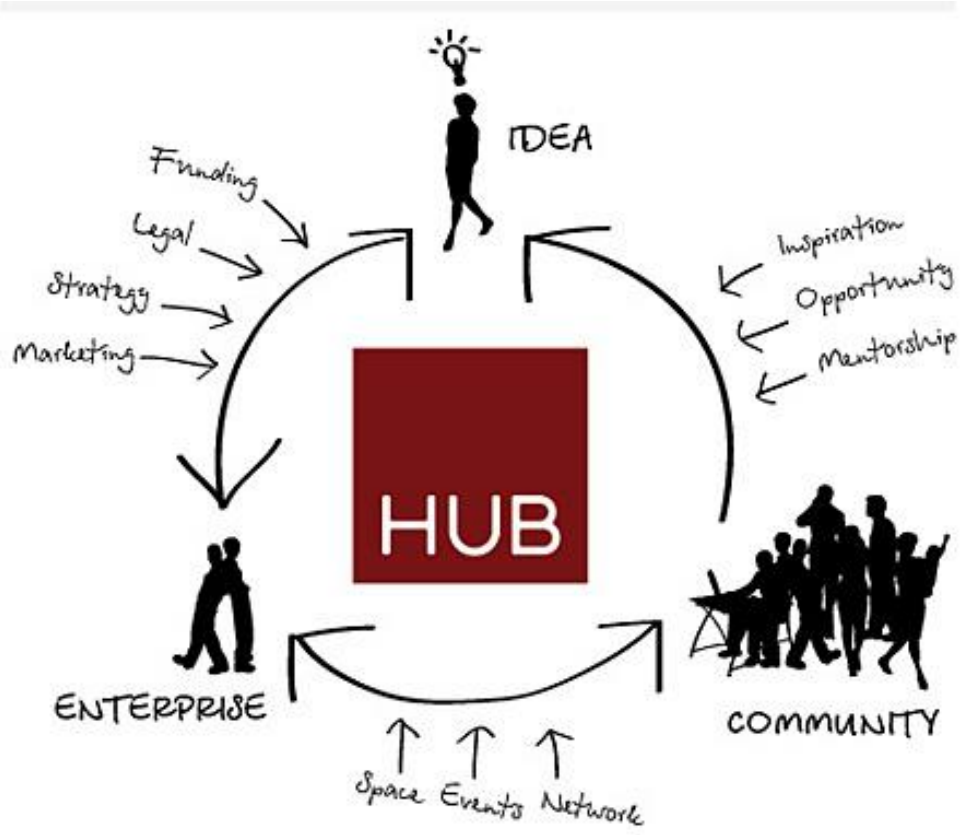
Hyper-Cooperative

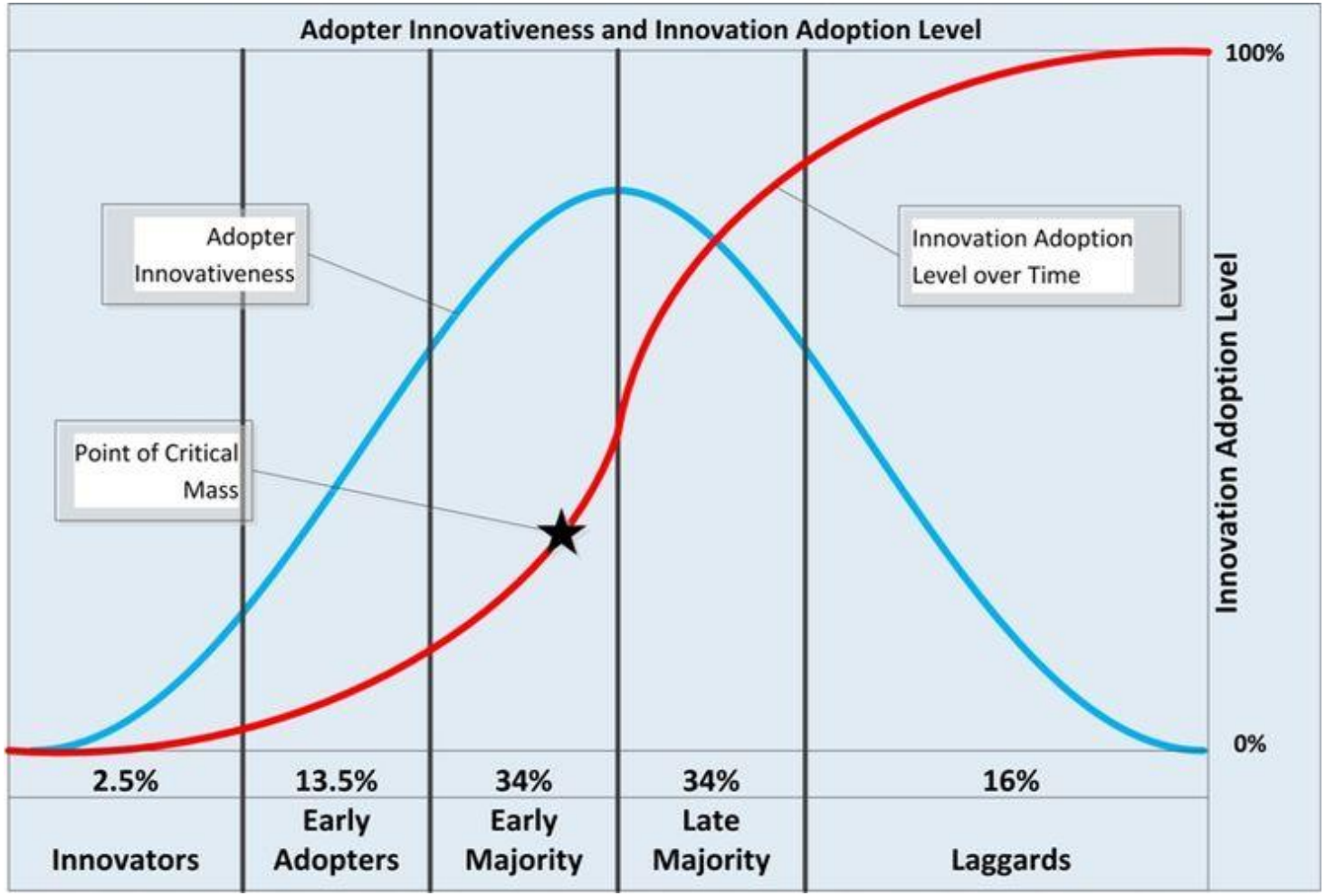
Hyper-Competitive/ utility maximizing

Maio et al. *WRR 2016*

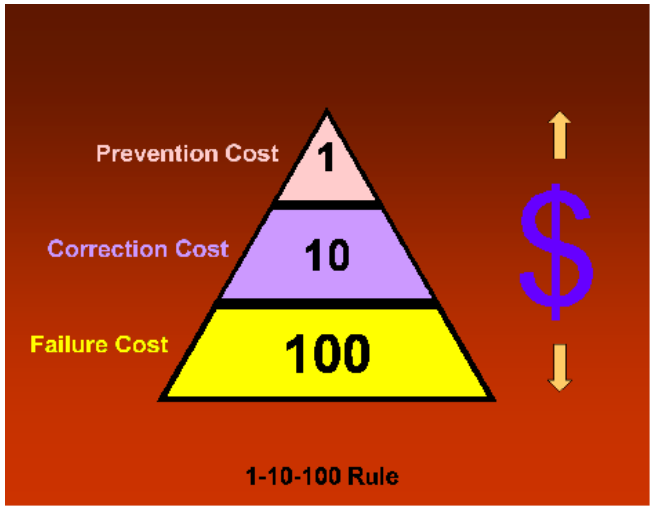
To Accommodate a Range of Human Responses: Market, Incentive and Regulatory Solutions are Needed

- To **shift mass balance of nutrients** going on and off of the landscape
- To encourage treatment of **nutrients as a commodity**
- To **incentivize adoption of best management practices** (BMPs, SOPs, etc.)
- To use **regulation** and **permitting** when level playing fields are needed and active resistance prevails





Reaching Our Point of Critical Mass…



"An ounce of prevention is worth a pound of cure."
Benjamin Franklin